Computational thinking competencies of Flemish college students: vision on data collection

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Abstract

Computational thinking has become an increasingly vital competence in our technologically driven world. As a problem-solving methodology, it can be considered a competence that transcends disciplines and plays an important part in multiple diverse fields. It has also gained a more prominent role in the Flemish education system. Therefore, assessing computational thinking and collecting the necessary data to do so has become increasingly important during students' education. This paper describes how the computational thinking competencies of college students can be monitored in a controlled environment. By combining a literature study as well as knowledge of the context wherein the data will be collected, a subset of data sources has been selected that show potential for a multimodal assessment of computational thinking. This paper outlines an envisioned data collection method to gauge computational thinking competencies among second-year computer science engineering students at Ghent University. The desired end result is a collection of data that can be managed and processed as an input source to assess computational thinking and affect educational practices. This paper describes a way of collecting data that shows potential for a multimodal assessment of computational thinking. It also opens the door for future research exploring the potential of AI-driven methods for automatic assessment and the development of interactive visualisation of said assessments.

1 Introduction

Computational thinking (CT) is a prerequisite for understanding and managing the possibilities, opportunities, consequences and risks of the digitisation of our world, including in the realm of information and communication [1]. This competence transcends disciplinary boundaries, becoming a fundamental competence across diverse fields [3]. In the context of Flemish secondary education, CT can be characterized as a process that involves six subconcepts; pattern recognition, generalisation, problem decomposition and abstraction, modelling of solutions and algorithm usage.[1, 4] It offers a better approach to tackling complex problems and empowers students to leverage computers in solving these challenges [1]. For each of these subconcepts, it's also important to properly apply them. Students may for example want to apply decomposition and split a problem into parts. While different approaches might initially lead to similar results, improper decoupling of responsibilities and consequently less effective decomposition might lead to future problems [8]. Nurturing this competence is thus of paramount importance, as individuals possessing it may be better positioned to leverage the ubiquitous computing in this world [5]. Current adaptive educational technologies aim to personalize learning experiences by leveraging the measurement, collection, analysis, and reporting of multimodal cognitive, metacognitive, affective, and motivational data [2]. However, the use of multimodal online

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trace data like log files or contextual data such as voice recordings can enhance our understanding of the learning process and provide a more comprehensive view of both the learner and the learning environment [2, 6]. A better understanding of this process and, consequently, a more context-sensitive approach can be very beneficial for educational technologies if they want to achieve educational goals. These technologies must evolve to become context-sensitive and thus more responsive to learners' characteristics and situations. Remaining stagnant and only working in terms of narrow cognitive attributes could lead to their ineffectiveness in achieving these goals [9].

Assessing CT with the aid of artificial intelligence holds significant promise, as it can assist educators to engage and support their students better. It equips educators with the ability to adapt to students' learning processes, receive suggested resources, and interact with computational resources [9]. Moreover, it could alleviate the burden on teachers when it comes to identifying learning challenges during in-lecture exercises, especially when dealing with large class sizes or time constraints [10]. The current lack of tools to assess the development of CT can partly be attributed to the lack of a unified definition and consensus on its incorporation into educational curricula [7].

This paper focuses on describing how we envision gauging and mapping computation thinking competencies among second-year engineering technology students at Ghent University during a computer science course. It outlines data collection methods as well as assessment instruments to map out student performance. This will result in a comprehensive dataset that is both manageable and processable while showing potential as an input source for a multi-modal assessment of CT. The envisioned end result encompasses diverse data types, including plain text, diagrams, and audio files. By combining these varied data sources, the dataset is intended to serve as input for artificial intelligence models, showcasing its desired potential for an automatic multi-modal evaluation of CT.

2 Methodology

The method we present revolves mainly around the selection of data inputs. This to accomplish our goal of constructing a diverse and comprehensive dataset with potential as an input source for a multi-modal assessment of CT. The selection process is driven by multiple factors such as the context of the data and the feasibility of using these data types as input for artificial intelligence models.

2.1 Educational context

The data will be collected in a Flemish educational context and take into account that the collected data and found results must be applicable to said context. Given the Flemish government's six-fold definition of CT; we considered data collection and assessment for the given concepts in this context to be a good representation of doing it for CT as a whole. This definition, however, is aimed at year 7 and year 8 in K-12 while we chose a computer science course at Ghent University. We made this decision because we can exert a high level of influence as supervisors and ensure a very controlled environment. This provides us with a method of mapping out and collecting different sorts of possible input data that could also be applied in K-12.

2.2 Course context

We will, as previously mentioned, collect data from students at Ghent University. To be more specific, all data will be collected during a second-year course called "Engineering Project" in the program "Bachelor of Science in Engineering (Computer Science Engineering)" in the academic school year 2023-2024. The lessons revolve around basic microcontroller programming. This course is estimated to have a workload of 75 to 90 hours spread over a combination of 11 lessons as well as a project students have to present by the end of the course. The lessons of this course are planned over 15 weeks and are primarily focused on giving students practical experience with microcontrollers. All theoretical knowledge is shared online at the start of the course through written text and video-based explanations. Students are expected to independently study this material by the third lesson, but questions can be asked throughout the course.

The 11 lessons consist of the following:

- Lesson 1: Receiving and testing of microcontroller platform.

- Lesson 2-3: Supervised practical exercises with microcontrollers.
- Lesson 4-11: Supervised time to work on the project.

Data collection will revolve exclusively around the project, as it exhibits the complexity required to assess all the components that define the Flemish government's CT description.

For the project, students are organized into pairs, with each pair programming their project using the Dwenguino platform, a microcontroller platform developed by Dwengo vzw. The Dwenguino platform integrates an AT90USB646 microcontroller and supports hardware components such as an LCD, LEDs, buttons, and a motor driver. To program the Dwenguino, students are mandated to use Visual Studio Code and PlatformIO, utilising AVR libraries and the provided datasheet. During the project, students are free to ask questions to supervisors and have to perform a stand-up to describe current progress, plans and challenges they encounter. The microcontroller platform is accessible to students only during the supervised lessons and cannot be taken home. Regarding the subject of the project, there are three choices;

1. Drawing table: In this project, students have access to a planar "robot arm" with two degrees of freedom, controlled by a servo motor. The goal is to use it to visualize complex figures on paper.
2. Accelerometer: The objective is to create a game where interaction is facilitated by the movement of the Dwenguino platform, with the board's movement measured using an accelerometer.
3. Infrared remote controller: In this project, students will establish wireless communication between two Dwenguino platforms using infrared light. For this, they will need to create their own communication protocol.

3 Data modalities to enable automatic assessment of computational thinking

As previously mentioned, our research aims to assemble a diverse dataset, spanning from plain text to diagrams and audio files. This selection process is guided by the Flemish educational context and the practicality of employing these data types as inputs for artificial intelligence models. As a result, we have chosen to collect the following data:

Diagrams to show the structure of the projects: Diagrams, created using draw.io, offer insights into how students apply CT concepts like problem decomposition, abstraction, and modelling. They showcase the students' ability to break down complex problems into manageable parts, conceptualize these components, and demonstrate how they interconnect. It also reveals the granularity students employ when applying these concepts.

Audio recordings of the weekly stand-up sessions: These depict how students plan their projects, as well as the challenges they face and the solutions they find. Decomposition, abstraction and modelling can be found in the way they solve the project as a whole by dividing it into parts and planning how they will solve these. Students may also notice and describe how some parts of the problem follow a pattern or that solutions or algorithms for a more generic, but relevant problem are applicable. Depending on the stand-up they may contain information about every subconcept used to describe CT.

Reports detailing the end result: These reports offer a written summary of implemented functionality, optimisation efforts, challenges faced, and their respective solutions. They serve as an extension of the audio recordings and a consolidated overview of the entire project, providing insights into students' problem-solving and CT processes.

Implementation of the project solutions: The written code represents the practical realisation of a group's solution. It encapsulates all the CT concepts, serving as a tangible manifestation of the drawn diagrams and planned solutions. The use of GitHub allows us to track how the code evolves, providing valuable insights into students' problem-solving progress.

Kanban boards: A kanban board, provided by GitHub, can be used to visually depict each stage of a project. During the project students are advised to use three stages; "To Do", "In progress" and "Done". Students use this tool to organize their projects, creating issues that detail project components that have to be implemented and problems to be solved. The Kanban board showcases students' step-wise planning and how it translates into practical solutions.

Our choice of these diverse data sources not only encompasses each subcomponent of CT but also leverages that the same underlying concepts can be discerned across different information and data inputs. This multifaceted approach also demonstrates how aspects of the project are addressed across various data inputs, emphasising the importance of gathering data from different sources to provide a more comprehensive context for understanding CT. Additionally, these data inputs serve as feasible inputs for artificial intelligence models, making them applicable for automatic CT assessments.

This data will only be collected from students who received an information letter and signed a consent form.

4 Conclusion

In conclusion, this research has unveiled our comprehensive vision for collecting and processing data to assess CT while underlining the pivotal role of incorporating context into the assessment process. Nevertheless, the practical implementation of this vision stands as a crucial next phase. Data collection and processing represent only the initial steps in the assessment process. Once the data has been cleaned and prepared, the focus must transition to automatically assessing the various subcomponents of CT. Identifying appropriate models and fine-tuning them constitutes an indispensable element of this process. Moreover, validating the automatic assessment by comparing it to human-made assessments will be an ongoing endeavour, fostering improvements in assessment methodologies.

Another crucial facet of our future work is the visualization of assessment data on a dashboard. To ascertain the most effective visualization methods for educators and their teaching practices, insights gathered through interviews with educators and a comprehensive literature study will serve as valuable guidance. These inputs will steer the development of visualizations that can empower teachers in their teaching activities.

As the educational landscape continues to evolve, the importance of assessing CT within a multifaceted context becomes increasingly evident. With the right data sources, methods, and visualization techniques, we have the opportunity to not only advance the understanding of CT but also to provide educators with practical tools to enhance their teaching practices. This work, in its essence, represents a stepping stone towards a more nuanced and context-sensitive approach to assessing and fostering CT, contributing to the broader effort of equipping students with essential competencies for the digital age.

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